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Ground Conductivity Survey for Beverage Antenna Site

San Clemente Island
21–24 May 1990

D. G. Fern

NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152-5000

J. D. FONTANA, CAPT, USN
Commander

H. R. TALKINGTON, Acting
Technical Director

ADMINISTRATIVE INFORMATION

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Released by
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W. R. Dishong, Head
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INTRODUCTION

In the search for a candidate site for a fast-wave very low frequency (VLF) Beverage antenna, the Naval Ocean Systems Center (NOSC) conducted a ground conductivity survey at its San Clemente Island facility from 21 to 24 May 1990. The survey was conducted at 12 sites around the island using a 4-stake Wenner array with a Biddle hand crank "Megger" ground resistance tester.

BACKGROUND

San Clemente Island is located approximately 80 miles west of San Diego, California. Rising to approximately 2000 feet above sea level at its highest point, the island is composed primarily of volcanic rock from the Miocene epoch (5 to 22.5 million years), and as such, is relatively recent in formation. This would suggest that the ground conductivity is reasonably high, as the conductivity of rock tends to decrease as its age increases. This tendency was borne out at San Clemente Island, since the conductivity found there was not extremely low (<0.001 mho/meter).

NOSC is actively involved in supporting the submarine communications capabilities of the U.S. Navy. One ongoing effort has been reconstitutible antennas. These are rapidly erectible antennas that are low efficiency, but low-cost installations. Several candidates have been examined, including the tethered aerostat, the crank-up tower, and the fast-wave Beverage antenna. The fast-wave Beverage has the advantage of being extremely low cost and having very large bandwidth in the VLF/LF range. The disadvantage is that it achieves this large bandwidth by being very inefficient. Nevertheless, for emergency use, it does have applications. The efficiency of the fast-wave Beverage antenna is greatly increased if it is placed over a low-conductivity earth (good dielectric). Therefore, a ground conductivity survey is of paramount importance in the site selection process for a Beverage antenna.

MEASUREMENTS

Twelve sites were used for the San Clemente Island survey. These sites are marked on the map of San Clemente Island shown in figure 1. The measurements were conducted approximately uniformly over the northern two-thirds of the island. The southernmost third of the island is used as a gunnery range and was inaccessible for our survey. The ground conductivity was conducted using a Wenner four-stake array. Figure 2 shows a diagram of this apparatus. A 60-Hz current is driven in the outer two stakes. This current flows through the ground and sets up an electric field along the ground surface. The inner two stakes measure the voltage induced along the surface of the ground due to the current in the outer two stakes. The voltage across the inner two stakes, divided by the current in the outer two stakes, is the mutual impedance between the two circuits. This mutual impedance is related to the ground conductivity of the earth in which the stakes are driven. In general, the earth comprises several layers, and the measured conductivity changes with the separation between the stakes. The resulting data is a plot of the apparent conductivity as a function of stake spacing. The layering of the earth can be deduced by the behavior of these plots.

Figures 3, 4, and 5 show the plots generated by the San Clemente Island measurements. Each graph corresponds to the physical location of the site measured. Figure 3 profiles sites 3, 10, 11, and 12. Figure 4 profiles sites 1 and 9. Figure 5 profiles sites 2, 4, 5, 6, 7, and 8. There is a considerable spread among all of the data taken; however, some general comments can be made. Sites 4 and 5 had the lowest conductivity. These sites have profiles that are essentially identical, which suggests that a low-conductivity "vein" may exist underneath and between these two sites. Sites 3, 7, and 9 have increasing conductivity with depth. This could be caused by any number of factors, however it is most likely due to subterranean streambeds or pools. Leaching of minerals into watersheds can also lead to unusually high conductivity profiles. In general, the ground conductivity decreases with depth. This finding is in line with expectations, as surface layers are often filled with water pockets or other sources of moisture. Underlying bedrock, unless it is heavily fractured and filled with groundwater through percolation, is generally of much lower conductivity than the surface layers. In this case, the low conductivity of the underlying rock is not much use as the antenna performance would be limited by surface-layer conductivity.

CONCLUSIONS

Previous work by Seeley (1986) shows that the radiation efficiency of a fast-wave Beverage antenna is proportional to the ratio f/σ, where f is the frequency, and σ is the ground conductivity. Seely asserts that very low conductivities (on the order of 1 millimho per meter or less) are required for a Beverage antenna to be reasonably efficient. "Reasonable" cannot be precisely defined since efficiency depends on several factors, including antenna size. A rough figure of merit of 1-percent efficiency could not easily be achieved at San Clemente Island. Conductivity at most of the sites on San Clemente Island was at least an order of magnitude higher than 1 millimho per meter; therefore San Clemente Island does not fall into Seeley's "favorable" category.

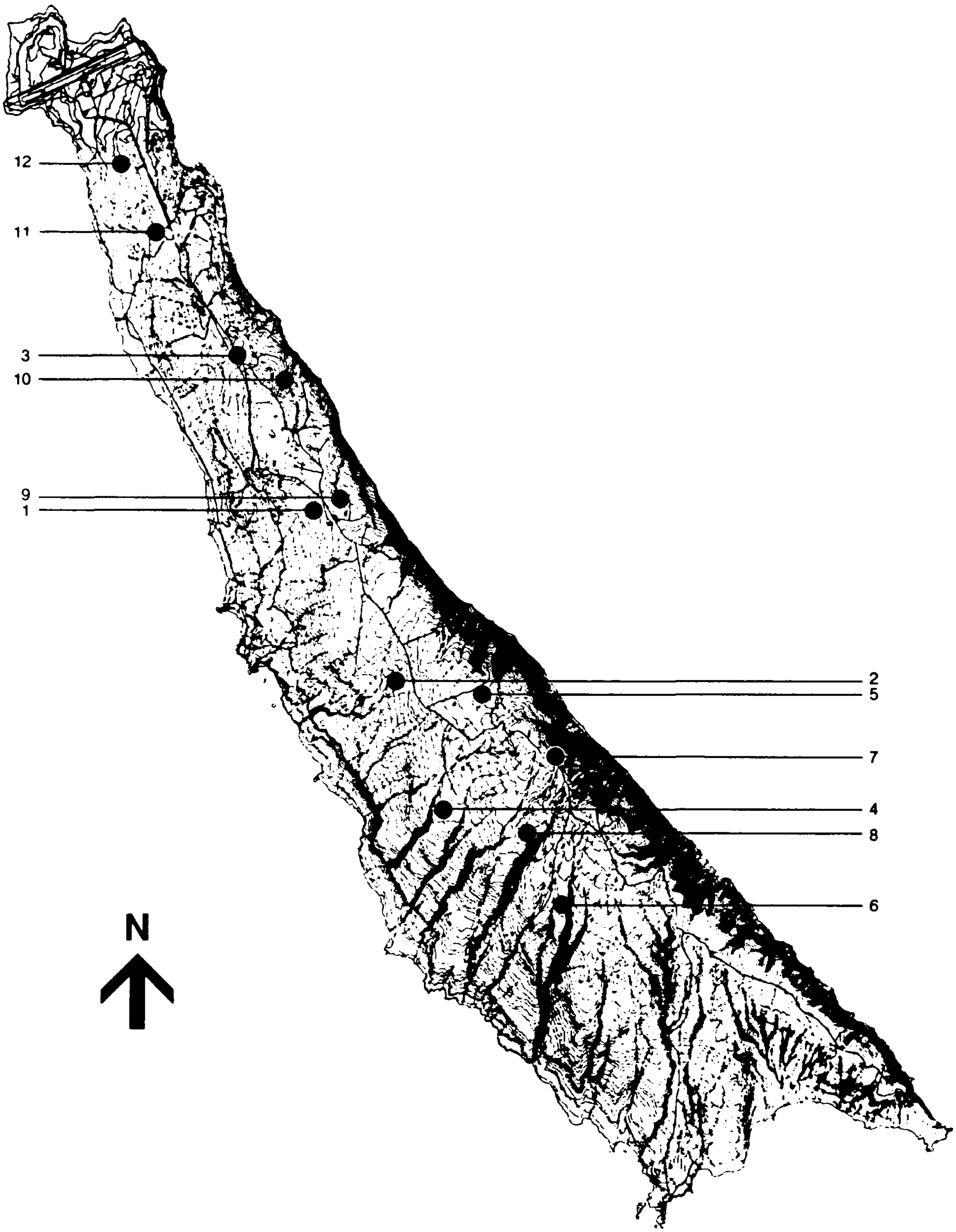


Figure 1. San Clemente Island survey sites.

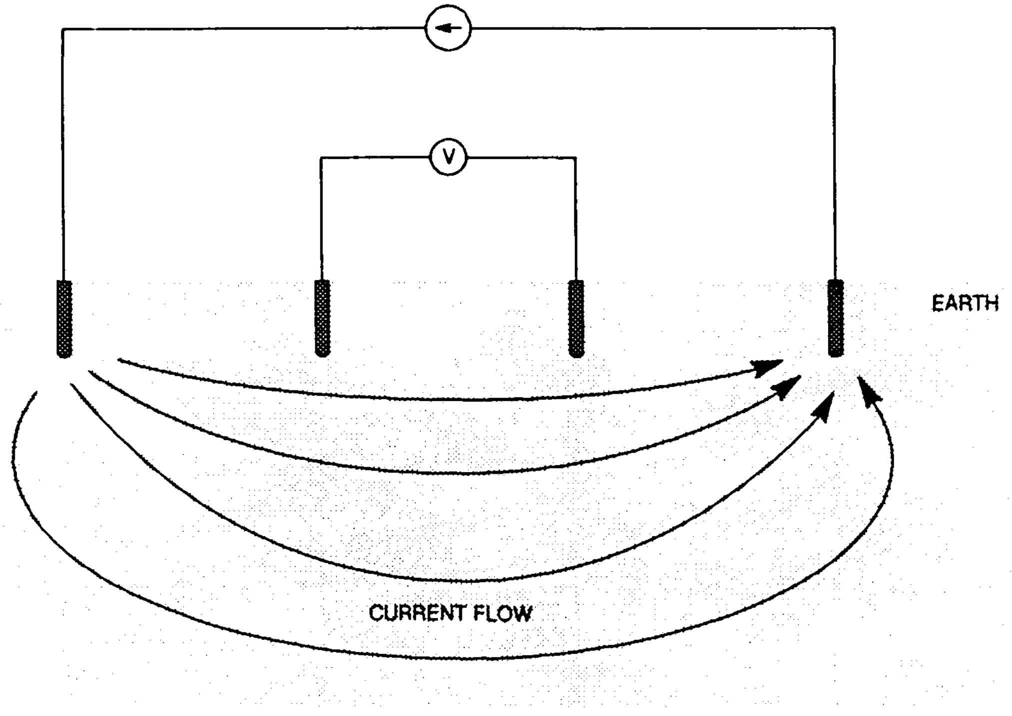
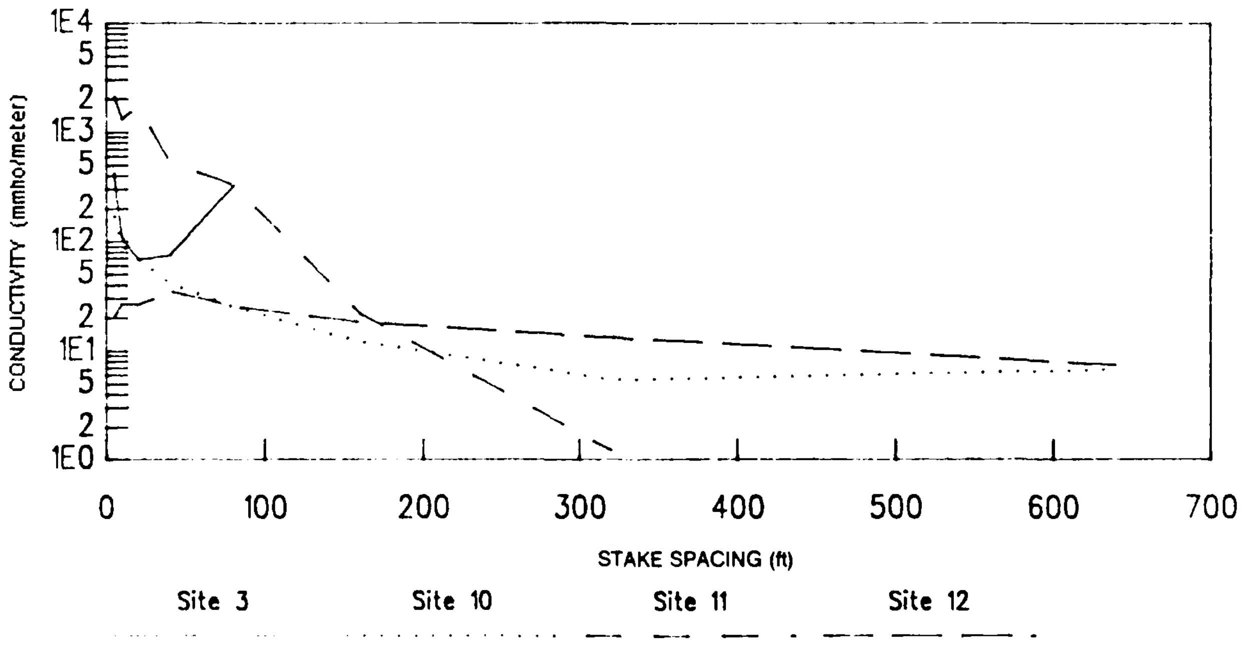


Figure 2. Wenner four-stake array.



Fi^ure 3. Conductivity profiles for sites 3, 10, 11, and 12.

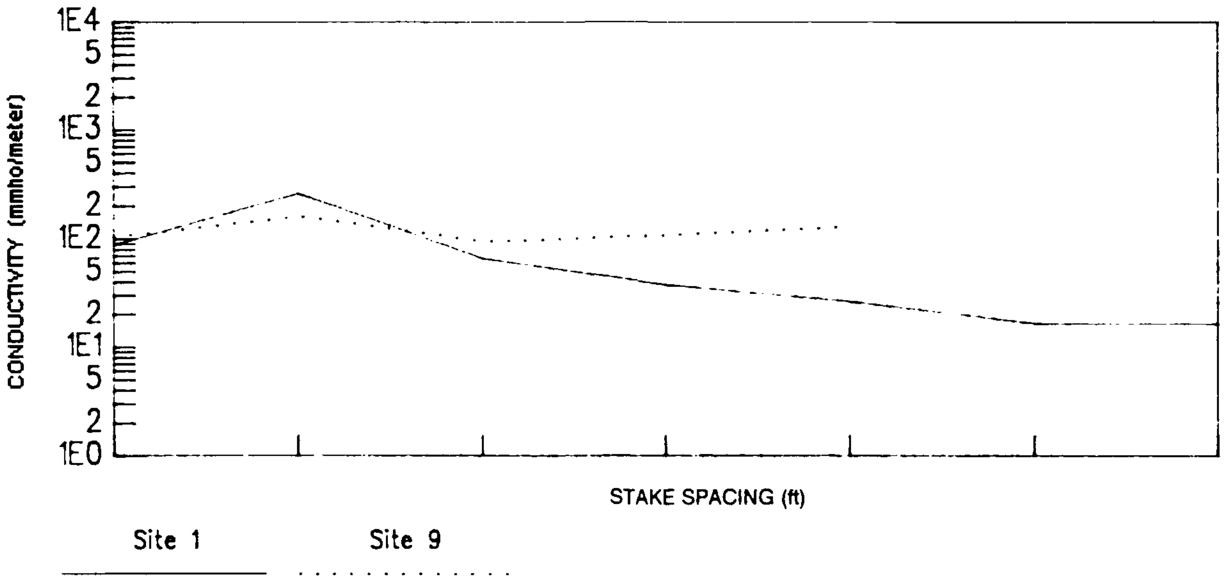


Figure 4. Conductivity profiles for sites 1 and 9.

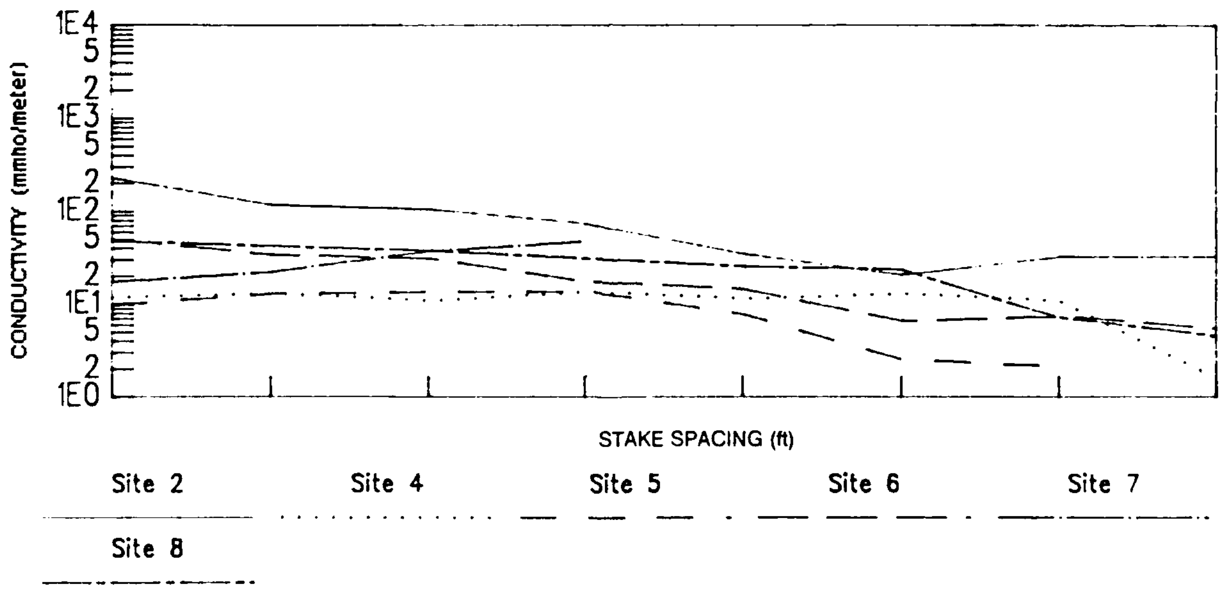


Figure 5. Conductivity profiles for sites 2, 4, 5, 6, 7, and 8.

REFERENCE

Seeley, E. W. 1986. "VLF/LF Horizontal Fast Wave Antenna Design Principles." Naval Ocean Systems Center Contract No. N66001-84-D-0134, 30 September 1986.

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